(12) UK Patent Application (19) GB (11) 2 259 287 (13) A

(43) Date of A publication 10.03.1993

(21) Application No 9118874.8

(22) Date of filing 04.09.1991

(71) Applicant
Rolls Royce plc

(Incorporated in the United Kingdom)

65 Buckingham Gate, London, SW1E 6AT,
United Kingdom

(72) Inventors
Norman Roberts
Susan Janet Riley
Robert Norman Carlin

(74) Agent and/or Address for Service
M A Gunn
Rolls-Royce plc, Patents Department, PO Box 31,
Moor Lane, Derby, DE2 8BJ, United Kingdom

(51) INT CL[5]
F02C 7/047, B64D 15/12

(52) UK CL (Edition L)
B7W W46A W46L
F1G GFC

(56) Documents cited
GB 2121745 A GB 1247071 A

(58) Field of search
UK CL (Edition K) B7W W46A W46D W46L, F1G GFC, F1V VCB
INT CL[5] B64D 15/00 15/02 15/04 15/12 15/14, F02C 7/04 7/047

(54) **Apparatus for and method of de-icing a surface**

(57) In order to facilitate de-icing of a leading edge (23) of an air intake duct (24) electrical heating apparatus is disposed immediately adjacent to the leading edge (23). The electrical heating apparatus comprises a number of wires (26) embedded in the leading edge (23). The wires (26) are heated intensely for a short period of time. The intense heating of the wires (26) results in a phase change at the interface between the leading edge (23) and the ice adhered thereto. The ice at the interface changes rapidly from a solid to produce a liquid and a gas. The adhesion of the ice is broken and the gas produced at the interface produces a force which is sufficient to detach the remaining ice from the leading edge (23). Instead of wires 26, stripes of electrically conductive paint or a conductive ceramic may be used, or a non-electric heat source may be used. A microwave detector or temperature detector sensing phase change or temperature at the interface may control the power supply.

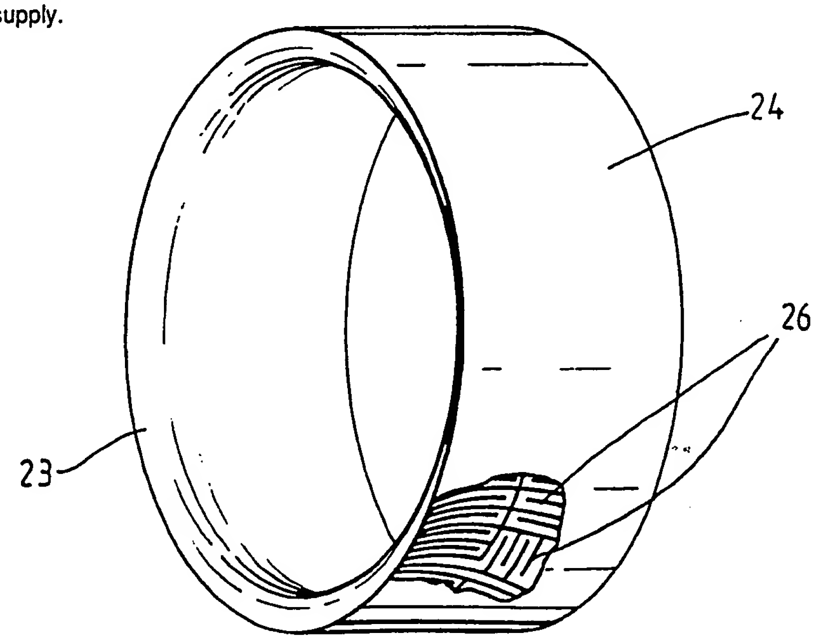

Fig.2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 259 287 A

1/1

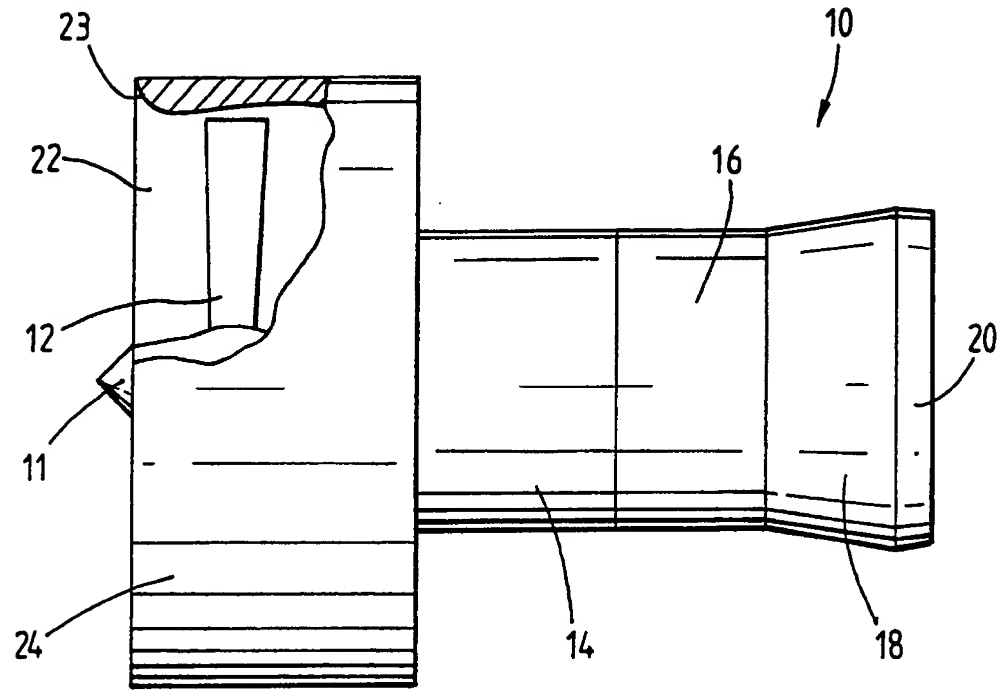

Fig.1

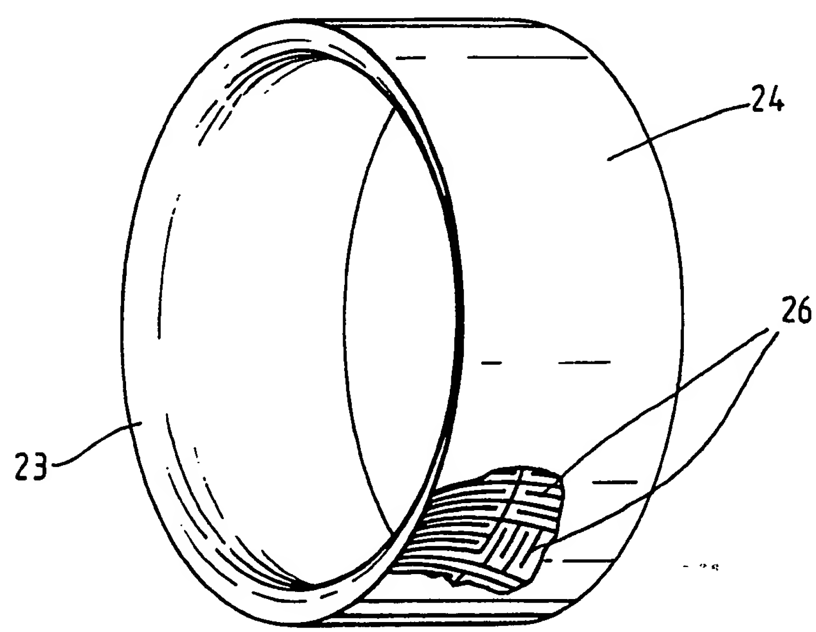

Fig.2

APPARATUS FOR DEICING A SURFACE AND METHOD OF USING THE SAME

The present invention relates to an apparatus for and method of de-icing a surface of an aircraft or aero-engine. In particular it is concerned with de-icing of the air intake of a gas turbine engine.

Icing of the leading edge of an air intake duct of a gas turbine aero-engine can occur during flight. At certain operating conditions water droplets entrained in the airflow freeze on impacting the intake. Ice formed on the intake can considerably restrict the airflow through the engine causing a loss in performance and possible malfunctioning of the engine.

Ice protection systems are therefore employed on the surfaces of air intakes which are susceptible to the formation of ice. These systems either prevent formation of the ice, anti-icing systems, or break up the ice that has already formed, de-icing systems. The system employed must be reliable, easy to maintain and present no extra weight penalty.

De-icing systems are known which use electrical heating apparatus to break up ice formed on the surfaces of an air intake. In order to reduce the electrical power demand required to de-ice large air intakes intermittent electrical heating is used.

Intermittent electrical heating allows ice to form during a period when no electrical power is provided but during a period when electrical power is provided the heat generated breaks the adhesion of the ice. The cycling time of the intermittent heating is arranged so that the engine can accept the amount of ice that collects during the power off period and yet ensures that during the power on period sufficient heat is generated to shed the ice whilst not adversely affecting the heated area. Once the adhesion of the ice is broken it is removed from the intake by aerodynamic forces.

The present invention seeks to provide an improved de-icing system which is not reliant on aerodynamic forces

to remove the ice once the adhesion of the ice has been broken.

According to the present invention apparatus for de-icing a surface on which in operation a layer of ice is adhered comprises a heater located adjacent to the surface to be de-iced, means for selectively energising the heater so that in operation when a layer or ice is adhered to the surface the heater is energised to heat the interface between the surface and the ice at such a rate that the ice at the interface vaporises and expands to produce a force sufficient to detach the remaining ice from the surface.

Preferably the heater is an electrical heating element. The electrical heating element in one embodiment of the present is a plurality of electrically conductive wires embedded in the surface.

In a second embodiment the electrical heating element is a series of thermally conductive paint stripes sprayed onto the surface.

In a third embodiment of the present invention the electrical heating element is a ceramic layer deposited onto the surface.

The means for selectively energising the heater may be a microwave detector which monitors the phase change at the interface between the ice and the surface. Alternatively the means for selectively energising the heater may be a temperature sensor which monitors the temperature at the interface between the ice and the surface.

The surface may form part of an air intake duct of a gas turbine engine.

A further aspect of the present invention is a method of de-icing a surface on which in operation a layer of ice adheres. The method comprises the steps of, locating a heater adjacent to the surface to be de-iced, selectively energising the heater so that the surface is heated when a layer of ice is adhered thereto, heating the surface so that the interface between the ice and the surface is heated at such a rate that the ice at the interface vaporises and expands to produce a force sufficient to detach the

remaining ice from the surface.

The present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a gas turbine engine which is partially broken away to show an air intake duct which is de-iced in accordance with the present invention.

Figure 2 is an enlarged view of the air intake duct in figure 1 which is partially cut away to show a de-icing system in accordance with one embodiment of the present invention.

Referring to figure 1 a gas turbine engine generally indicated at 10 comprises a fan 12, a compressor 14, combustion equipment 16, a turbine 18 and a fixed propulsion nozzle 20 in flow series. An annular air intake 22 is provided between the hub 11 of the fan 12 and an air intake duct 24. The air intake duct 24 is manufactured from a carbon fibre reinforced composite material.

In order to allow de-icing of leading edge 23 of the air intake duct 24 electrical heating apparatus is disposed immediately adjacent the leading edge 23. The electrical heating apparatus comprises a number of wires 26 which are embedded into the leading edge 23 of the air intake duct 24, figure 2. The wires 26 are disposed between the layers of carbon composite material which form the air intake duct 24. The carbon composite material comprises layers which are bound together by a resin which acts to insulate the wires 26 from one another.

The wires 26 are electrically conductive and an electrical current is supplied to them by a generator (not shown). The wires 26 offer a resistance to the electrical energy passing therethrough. The resistance to the electrical energy causes the wires 26 to heat up which in turn causes heating of the leading edge 23 of the air intake duct 24.

The wires 26 are intermittently heated by cycling the electrical energy supply from the generator. When no electrical energy is supplied ice builds up on the leading

edge 23 of the air intake duct 24. The presence of a layer of ice is detected by a vibrating sensor. The frequency at which the sensor vibrates changes when ice has formed thereon. There are a number of alternative sensors commercially available which may be used to detect the presence of ice on the air intake duct 24.

When a layer of ice has been detected of if an operator so demands electrical energy is supplied to the wires 26 so that they are heated intensely for a short period of time. The intense heating of the wires 26 results in a phase change occurring at the interface between the ice and the leading edge 23 of the air intake duct 24. The layer of ice adhered to the leading edge 23 of the air intake duct 24 changes rapidly from solid ice to produce a liquid and a gas at the interface. The adhesion of the ice is broken and the expansion experienced with the production of the gas produces a force which is sufficient to detach the remaining ice from the leading edge 23.

In the preferred embodiment of the present invention the phase change at the interface of the ice and the leading edge 23 of the air intake duct 24 is monitored by a microwave detector (not shown). The microwave detector is embedded in the carbon composite layers of the air intake duct 24 and measures the amount of microwaves backscattered to the detector. The amount of microwaves detected will change according to whether the interface is all ice, water and ice or partially gas. The detector in turn controls the electrical supply to the wires 26 so that electrical power is not supplied once the presence of a gas at the interface has been detected.

Only short impulses of electrical power which are high in intensity are required to de-ice the air intake duct 24. The change of phase which occurs in the layer of ice which adheres to the leading edge 23 of the air intake duct 24 provides a force sufficient to detach the remaining ice rather than relying on aerodynamic forces.

In a second embodiment of the present invention a thermally conductive paint is used to heat the leading edge

23 of the air intake duct 24. A mask is used to produce a series of stripes in a layer of paint which is sprayed onto the leading edge 23 of the air intake duct 24. The stripes are thermally conductive and are sequentially heated. Optimum sequencing of an electrical supply to the paint stripes reduces the power requirements needed to de-ice the air intake duct 24. The paint stripes offer the advantage that they are readily accessible and easy to repair as they lie on the surface of the air intake duct 24.

In a further embodiment of the present invention a ceramic layer is deposited onto the leading edge 23 of the air intake 24. A ceramic such as Ceram 60 produced by Schott Industries is used as it heats up rapidly to vaporise the ice.

Although the present invention has been described with reference to electrical heater elements it will be appreciated that alternative heating means could be used. Further a temperature sensing device may be used in place of the microwave detector. The temperature detector would monitor the temperature of the wires 26 and control the amount of electrical energy supplied.

The present invention has been described with reference to an air intake of a gas turbine engine however it will be appreciated that it is equally applicable to any surfaces which are susceptible to the formation of ice.

Claims:

1. Apparatus for de-icing a surface on which in operation a layer of ice is adhered comprises a heater located adjacent to the surface to be de-iced, means for selectively energising the heater so that in operation when a layer of ice is adhered to the surface the heater is energised to heat the interface between the surface and the ice at such a rate that the ice at the interface vaporises and expands to produce a force sufficient to detach the remaining ice from the surface.

2. Apparatus as claimed in claim 1 in which the heater is an electrical heating element.

3. Apparatus as claimed in claim 2 in which the electrical heating element is a plurality of electrically conductive wires embedded in the surface.

4. Apparatus as claimed in claim 2 in which the electrical heating element is a series of thermally conductive paint stripes sprayed onto the surface.

5. Apparatus as claimed in claim 2 in which the electrical heating element is a ceramic layer deposited onto the surface.

6. Apparatus as claimed in any of claims 1-5 in which the means for selectively energising the heater is a microwave detector which monitors the phase change at the interface between the ice and the surface.

7. Apparatus as claimed in any of claims 1-5 in which the means for selectively energising the heater is a temperature sensor which monitors the temperature at the interface between the ice and the surface.

8. Apparatus as claimed in any preceding claims for use in a surface which forms part of an air intake duct of a gas turbine engine.

9. A method of de-icing a surface on which in operation a layer of ice adheres, the method comprising the steps of,
locating a heater adjacent to the surface to be de-iced,
selectively energising the heater so that the surface is heated when a layer of ice is adhered thereto,
heating the surface so that the interface between the

surface and the ice is heated at such a rate that the ice at the interface vaporises and expands to produce a force sufficient to detach the remaining ice from the surface.

10. Apparatus for de-icing a surface as hereinbefore described with reference to and as shown in figures 1 and 2.

11. A method of de-icing a surface as hereinbefore described with reference to figures 1 and 2.

Examiner's report to the Comptroller under Section 17 (The Search Report)

9118874.8

Relevant Technical fields

(i) UK Cl (Edition K) B7W-W46A,W46D,W46L F1F-GFC; F1V-VCB

(ii) Int Cl (Edition 5) B64D-15/00,15/02,15/04,15/12, 15/14 F02C-7/04,7/047

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

B F BAXTER

Date of Search

21 FEBRUARY 1992

Documents considered relevant following a search in respect of claims 1-9

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2121745 A (WESTLAND) whole document	1,9
A	GB 1247071 A (ROLLS-ROYCE) whole document	1,9

Category	Identity of document and relevant passages	Relevant to claim(s,

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).